Method and Apparatus to Correlate Aircraft Flight Tracks and Events with Relevant Airport Operations Information

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a Continuation-In-Part application of U.S. Patent Application Serial No. 10/638,524, filed August 12, 2003, entitled "METHOD AND APPARATUS FOR IMPROVING THE UTILITY OF AUTOMATIC DEPENDENT SURVEILLANCE", which is incorporated herein by reference in its entirety, which in turn is a Continuation of U.S. Patent Application Ser. No. 09/516,215, filed on February 29, 2000, which in turn claims priority from Provisional Application Ser. No. 60/123,170, filed March 5, 1999, both of which are incorporated herein by reference in its entirety.

[0002] The present application is also a Continuation-In-Part of U.S. Patent Application Ser. No. 10/319,725, filed December 16, 2002, entitled "VOICE RECOGNITION LANDING FEE BILLING SYSTEM", incorporated herein by reference in its entirety.

[0003] The present application is also a Continuation-In-Part of U.S. Patent Application Ser. No. 10/457,439, filed June 10, 2003

entitled "Correlation of Flight Track Data with Other Data Source", incorporated herein by reference in its entirety.

[0004] The present application also claims priority from Provisional U.S. Patent Application No. 60/440,618, filed January 17, 2003, incorporated herein by reference in its entirety.

[0005] The subject matter of the present application is also related to that in U.S. Patent Application Ser. No. UNASSIGNED (Attorney Docket No.RANN-0015) entitled "METHOD AND APPARATUS FOR ACCURATE AIRCRAFT AND VEHICLE TRACKING" (Alexander E. Smith et al.), incorporated herein by reference.

[0006] The subject matter of the present application is related to the following issued U.S. Patents, assigned to the same assignee as the present invention, all of which are incorporated herein by reference in their entirety:

U.S. Patent No. 6,049,304, issued April 11, 2000, entitled "Method and Apparatus for Improving the Accuracy of Relative Position Estimates In a Satellite-Based Navigation System";

U.S. Patent No. 5,999,116, issued December 7, 1999, entitled "Method and Apparatus for Improving the Surveillance Coverage and Target Identification in a Radar Based Surveillance System";

U.S. Patent No. 6,094,169, issued July 25, 2000, entitled "Passive Multilateration Auto-Calibration and Position Error Correction";

U.S. Patent No. 6,384,783, issued on May 7, 2002, entitled "Method and Apparatus for Correlating Flight Identification Data With Secondary Surveillance Radar Data";

U.S. Patent No. 6,633,259, issued October 14, 2003, entitled "METHOD AND APPARATUS FOR IMPROVING THE UTILITY OF AUTOMATIC DEPENDENT SURVEILLANCE";

U.S. Patent No. 6,211,811, issued April 2, 2001, entitled "Method and Apparatus for Improving the Surveillance Coverage and Target Identification in a Radar Based Surveillance System";

U.S. Patent No. 6,448,929, issued September 10, 2002, entitled "Method and Apparatus for Correlating Flight Identification Data With Secondary Surveillance Radar Data"; and

U.S. Patent No. 6,567,043, issued May 20, 2003, entitled "METHOD AND APPARATUS FOR IMPROVING THE UTILITY OF AUTOMATIC DEPENDENT SURVEILLANCE".

FIELD OF THE INVENTION

[0007] The present invention relates to a method and apparatus for tracking aircraft flight patterns. In particular, the present

invention is directed toward a method and apparatus to correlate aircraft flight tracks and events with relevant airport operations Information.

BACKGROUND OF THE INVENTION

[0008] The AirScene™ system, developed by Rannoch Corporation of Alexandria Virginia, can track air traffic using multilateration and other techniques. Rannoch Corporation and its staff members have an extensive background in air traffic control, as well as noise operations and flight tracking, and thus has an understanding of not only how to detect and track aircraft and aircraft noise, but how to understand how and why aircraft noise is created and why aircraft follow particular tracks.

[0009] In order to try and understand the operations around an airport, the user must also understand what is happening at the airport. Simply looking at a real-time or recorded flight track and an associated noise event is only a part of the overall picture. While a Prior Art noise monitoring system might be able to tell the user how much noise is generated, and where, it may not tell the more important answer as to why the noise is generated and how it can be attenuated. Oftentimes various

circumstances may create a scenario where noise is generated inadvertently.

[0010] The other major Noise Operations and Monitoring Systems (NOMS) on the market usually offer some form of flight tracking, correlation of noise event, and correlation with complaints. Most of the major NOMS systems, including AirScene™ allow some form of "gating" to automatically filter large numbers of flights where the user need only look at aircraft that exceeded certain parameters or transgressed certain boundaries.

[0011] For example, gating will automatically identify that an aircraft did not follow a standard instrument departure as it turned too early or the like. As the reader is likely aware these transgressions and exceedances occur many times on an ongoing basis at our nation's airports. The question is why?

[0012] For example, a user may wish to know why an aircraft turned 20 degrees west two miles earlier than the noise abatement procedure stated. Or why did the aircraft on approach to 27 Left go around two times before landing. Or why were northwest departures being used at night. Or why were cargo airlines using runway 24 between 4 and 6 am for departures. Any of these events may contribute to excessive noise. Without understanding a cause

and effect relationship between these events and the noise created, it may be difficult to reduce noise around an airport.

[0013] Answers to these and many other similar questions are often based on a combination of many factors. Airport Operations may be an underlying cause of noise problems, as operations on the ground may force a pilot to alter his approach in a manner which may violate noise reduction edicts. Examples of airport operations parameters may include: Runways and types of approaches in use; Runway category of operation (Category I, II, III); Runway visual range (visibility on each runway); Airports operating in instrument of visual conditions (IFR/VFR operations); NOTAMS in effect ("notices to airmen"); Status of radar services at the airport and other nearby airports; Runways that are closed; Portions of taxiways that are closed; Construction crews working at the airport; Average runway occupancy time by aircraft type; and Average taxi time by aircraft type.

[0014] Another factor to consider is airport weather conditions. These conditions may include: Wind speed, directions, gusting; Wind shear alert; Visibility; Precipitation; Snow; Runway conditions, standing water, ice, and the like; Cloud ceiling; Temperature; and Dew point. Yet another factor to consider may include Air Traffic Control (ATC) Instructions. These

instructions may include NOTAM instructions, Aircraft clearances, and Aircraft directions.

[0015] Another factor may include Aircraft Equipage, which may include: Aircraft approved category to land (Category I, II, III); Flight Management Systems (FMS); Aircraft Communications, Addressing and Reporting System (ACARS); Glass cockpit; Traffic Alert and Collision Avoidance System (TCAS); and Head Up Display (HUD).

[0016] In the Prior Art, all of this data was not available. Correlating aircraft flight tracks, noise data, and other related aircraft, airport, and environmental data, would require difficult and time-consuming manual labor. Making the connection between conditions on the ground, for example, and a noise event may have proved difficult. Prior Art noise monitoring systems could do little other than determine which aircraft are in violation of noise rules - without determining the underlying causes of the noise violations.

[0017] What remains a requirement in the art, therefore, is a system which can acquire and store all types of aircraft, airport, and environmental data, as well as aircraft tracking and noise data, and allow a user to correlate or filter such data to

discover trends between different data scenarios. And thus a requirement remains in the art for a system that not only tracks aircraft flight, departure, and arrival patterns, but also a system which can provide information as to why such patterns occur.

SUMMARY OF THE INVENTION

[0018] Depending on the equipage at a particular airport, AirScene™ of the present invention may provide the above information, automatically and digitally. Therefore, answers may be available to the question noted above.

[0019] For example, a possible answer to the question, "Why did the aircraft turn 20 degrees west two miles earlier than the noise abatement procedure stated?" might be that the aircraft is an older DC-8 cargo aircraft, with no Flight Management System (FMS), which was unable to closely follow the advanced departure path for the recommended noise abatement procedure.

[0020] Similarly, the possible answer to the question "Why did the B-737 on approach to Runway 27 Left go around two times before landing?" might be that marginal Category I visibility and ceiling

conditions existed, and the aircraft was equipped for Category I operations only. The Aircraft performed a go-around until both ceiling and visibility requirements were met. Otherwise the aircraft would have re-directed to another airport.

[0021] A possible answer to the question of "Why were northwest departures being used at night?" might be taxiway and runway maintenance. A possible answer to the question of "Why where the cargo airlines using runway 24 between 4 AM and 6 AM for departures?" might be a fuel spill on main runway.

[0022] The answers to these questions may allow airport operators, planners, pilots, and airline operators to better manage airport, airline, and airplane operations so as to reduce instances of noise violations and better manage airport operations. Having ongoing automated access to data on airport operations, airport weather, ATC instructions, and aircraft equipage allows airport management to understand why certain operations are happening and causing complaints, not just to observe the effects.

[0023] AirScene™, through a unique data fusion process, is the only NOMS system to provide such data, digitally, and in a form that is integrated with flight tracks, noise events, complaint,

and operations data. Other systems provide only the flight track, noise event and complaint data, and a manual recording of various ATC frequencies. Therefore other approaches do not offer any type of automated correlation of operational information with noise and flight track data. AirScene™ offers users the ability to record, search and query vast numbers of records using all of the above parameters, where available.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Figure 1 is an example of a data query, which identifies those aircraft that exceeded gate parameters when conducting IFR landings to runway 23L, and when noise complaints were recorded and there was construction at the airport.

[0025] Figure 2 is an example of a query, which identifies flight paths of aircraft exceeding noise event parameters when conducting night departures for runway 28R during a predetermined period of January through March 2002.

[0026] Figure 3 is a transcript of an actual recording of an ATIS report made at DuPage Airport, West Chicago, Illinois in July 1996.

[0027] Figure 4 is a table listing examples of airports using ACARS for D-ATIS as of 2002.

[0028] Figure 5 is a weather sample taken from http://weather.noaa.gov/weather/current/KIAD.html.

[0029] Figure 6 is a 24-hour weather sample taken from http://weather.noaa.gov/weather/current/KIAD.html.

[0030] Figure 7 is a table illustrating the combinations and automatic classifications possible with the logic of Figure 9.

[0031] Figure 8 is a diagram illustrating approach paths in an example where the airport is running standard approaches into Runway 12.

[0032] Figure 9 is an example of Logic used to Classify Operational Events.

DETAILED DESCRIPTION OF THE INVENTION

[0033] AirScene™ through a unique data fusion process is the only NOMS system to provide such data, digitally, and in a form that is integrated with flight tracks, noise events, complaint, and operations data. Other systems provide only the flight track, noise event and complaint data, and a manual recording of various ATC frequencies. Therefore other approaches do not offer any type of automated correlation of operational information with noise and flight track data. AirScene™ offers users the ability to record, search and query vast numbers of records using all of the above parameters, where available. For example, using this unique fusion process it is possible to run the following query combinations as illustrated in Figure 1.

[0034] Figure 1 is an example of a data query, which identifies those aircraft that exceeded gate parameters when conducting IFR landings to runway 23L, and when noise complaints were recorded and there was construction at the airport. Through the graphical user interface (GUI) of AirScene™ as illustrated in Figure 1, a user may select data types for which to filter aircraft tracking data. The resultant data may be compared to periods when there was not ongoing construction to determine whether certain construction were causing noise complaints. If this was the case

the airport may look to see, for example, if Air Traffic Control (ATC) had changed arrival procedures to runway 23L as a result of the construction.

[0035] Figure 2 is an example of a query that identifies flight paths of aircraft exceeding noise event parameters when conducting night departures for runway 28R during a predetermined period of January through March 2002 for aircraft not equipped with Flight Management Systems (FMS). By selecting various filtering parameters from the drop-down menu in the AirScene™ GUI, the user can quickly generate a graphical representation of flight tracks meeting the filtering criteria. In the example of Figure 2, it may be determined, for example, that the lack of a Flight Management System in the aircraft during nighttime cross-wind landings, may have resulted in deviations from the preferred noise abatement approaches.

[0036] Aircraft flight track data, as well as noise data may be acquired using any one of the number of techniques disclosed in the co-pending and issued Patents to Rannoch Corporation cited above. These Patents and pending applications describe various aspects of embodiments of the AirScene™ system sold by Rannoch Corporation which provides flight track data, generally though use of multilateration techniques. The present invention represents

an improvement to the AirScene™ system in that it allows AirScene™ flight track data to be fused with data from other sources.

[0037] These other sources may provide data in a number of formats, either electronically, or they may be manually entered. Examples of such data sources are described as follows. The present invention is not limited to these data sources, but may also include other data sources within the spirit and scope of the present invention.

[0038] A first source of data is the conventional Voice Automated Terminal Information Service (ATIS). ATIS comprises recorded information, which is broadcast continuously over designated frequencies. The air traffic control tower prepares this information to provide arriving and departing traffic information pertaining to active runways, weather conditions and notices to airmen (NOTAMS). The wind information in an ATIS transmission is given in a magnetic direction. When airport conditions change, the tower will record a new report.

[0039] When an ATIS is recorded it is assigned a letter using the phonetic alphabet. When calling the tower, ground control or approach control a pilot may advise that he or she has "information Charlie". This indicates to the controller that the

pilot has heard the latest ATIS transmission and the controller need not repeat it. Figure 3 is a transcript of an actual recording of an ATIS report made at DuPage Airport, West Chicago, Illinois in July 1996. The table provides a description of the contents of this particular ATIS report as illustrated in Figure 3.

[0040] ATIS broadcasts originate from most major airports. The frequency can be found on any aeronautical chart next to the symbol for the airport. If an ATIS exists, the frequency will be shown next to the letters "ATIS". From the Aeronautical Information Manual (AIM), ATIS is defined as "The continuous broadcast of recorded non-control information in selected terminal areas. Its purpose is to improve controller effectiveness and to relieve frequency congestion by automating the repetitive transmission of essential but routine information."

[0041] Another example of an analog voice recorded ATIS Broadcast for Cleveland might be as follows:

> "Cleveland Hopkins Information India,
> 1755 Zulu Automated Weather
> Wind 260 at 15 gust 19
> Visibility 6, light snow
> 2,600 broken, 3,500 overcast
> Temperature -5
> Dew point -11
> Altimeter 2999

ILS runway 23 left approach in use
Landing runway 23 left
Departing runway 23 right
Notice to airmen, runway 18 closed
Read back all runway assignments and hold short instructions
Use caution for birds in the vicinity of the active runway
Advise the controller on initial contact, you have India"

[0042] The Cleveland ATIS Broadcast quoted above may be summarized as follows in Table A:

Topic	**Example**
ATIS information identifier letter	Information India
Time of Report	1755 Zulu
Wind Direction/Speed	260 at 15 gusting to 19
Visibility	6 miles, light snow
Ceiling	2,600 Scattered, 3,500 Overcast
Temperature	-5
Dew Point	-11
Altimeter	29.99
Instrument Approach and Runways in use	ILS (Instrument Landing System) runway 23 Left in use Landing 23 Left, Departing 23 Right
Notices to Airmen Taxiway/runway closures, lights, etc.	Runway 18 closed

TABLE A

[0043] This data may be generated electronically at each airport and broadcast in voice form using a speech generation system. Alternately, recorded or live broadcasts may be used. In the present invention, this data may be entered into the system manually, or may be electronically entered using voice recognition

systems or the like, or via electronic link to the airport control tower. Regardless of the link used, the ATIS represents a source of airport and environmental data, which the present invention may use for data fusion and correlation with aircraft tracking data.

[0044] Another source of similar information is the Digital Automated Terminal Information Service (D-ATIS). In order to more effectively make use of bandwidth, airports are now making ATIS information available digitally over data links. These services allow pilots of participating aircraft to receive airport status and weather information for any participating airports. The Aircraft Communications and Reporting System (ACARS) is one of the data links being used for the transfer of D-ATIS. The table in Figure 4 lists examples of airports using ACARS for D-ATIS as of 2002.

[0045] D-ATIS has several advantages over voice ATIS. It is available regardless of the airplane's distance from the airport. Voice ATIS is only available within VHF range of the airport. The pilot gets a clear printout of the ATIS information. Poor quality of voice transmissions and accent problems are avoided. It also saves time during a period of high workload in the cockpit. D-ATIS also provides a means by which ATIS data can be electronically input into the AirScene™ system of the present

invention. Local airport data can be input into the AirScene™ system using an existing data link. Alternately, airport data for remote airports can be input into the AirScene™ system if data analysis for a remote airport or airports is desired.

[0046] The following is an example of D-ATIS message from Copenhagen Airport (EKCH), Denmark:

```
EKCH ARR ATIS U
1450Z
EXP EXP ILS APP
RWY 22L
COND RWY WET WITH PATCHES
TRL 55
REDUCED SEPARATION
PROCEDURES APPLIED ON
FINAL.
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The following is an example of D-ATIS message from Frankfurt Airport (EDDF), Germany:

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EDDF ARR ATIS C
1620Z - ATIS C RWY: 25/18
TL:60 SR:0513 SS:1724
ETOU RWY:26
-METAR 241620 EDDF
18006KT
A:1500P B:1500P C:1500P
E:1500P F:1500P G:1500P
I:1500P K:1500P L:15
00P
-CAVOK 24/11
-1016
-NOSIG
COMMENTS: WIND 18:
19003KT VIS: 70KM
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The following is an example of D-ATIS message from Newark Airport (KEWR), USA:

```
KEWR ARR ATIS O
1751Z EWR ATIS INFO O 1751Z.
16010KT 9SM FEW018 BKN080 23/18 A3008 (THREE ZERO ZERO
EIGHT).
ILS RWY 22L APCH IN USE.
DEPARTING RWY 22R.
RWY 11/29 CLSD.
NORTH 4 HUNDRED AND FIFTY FEET OF RY 22R CLSD.
RY 22R ALD 9 THOUSAND 5 HUNDRED AND FIFTY.
RY 22R DEPARTURES AUTHORIZED FROM INTERSECTION Y,
AVAILABLE DEPARTURE DISTANCE 9 THOUSAND 5 HUNDRED AND FIFTY.
COA RAMP PROCEDURES IN EFFECT.
READBACK ALL RUNWAY HOLD SHORT INSTRUCTIONS.
USE CAUTION FOR BIRDS AND CRANES IN THE VICINITY OF EWR.
...ADV YOU HAVEINFO O.57DE
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[0047] The D-ATIS data includes not only weather data, but also airport data such as runway closings and the like. Other potential sources for airport specific weather data includes Airport Weather Observation Systems (AWOS), Low Level Wind shear Alert Systems (LLWAS). Use of the Aircraft Communication Addressing and Reporting System (ACARS) for correlating data is found in U.S. Patent Nos. 6,384,783 and 6,448,929, cited above.

[0048] Internet sources exist for current weather at airports, including in the United States the U.S. Department of Commerce National Oceanic and Atmospheric Administration (NOAA). A weather

sample from http://weather.noaa.gov/weather/curret/KIAD.html is illustrated in Figures 5 and 6.

[0049] Yet other sources for data for the present invention may include Terminal Aerodrome Forecast (TAF) and METAR, the latter of which is a French acronym for Routine Aviation Weather Report. Some of the data in TAF and METAR may be redundant when compared with Digital ATIS. However, at airports that do not have Digital ATIS, TAF and METAR data may be especially useful. TABLE B illustrates a sample of weather summary data for KPHX (Phoenix Sky Harbor Airport) illustrating METAR and TAF forecast data.

KPHX	Data Messages
METAR	METAR KPHX 121356Z 11006KT 10SM CLR 27/07 A2991 RMK AO2 SLP110 T02670067
TAF	TAF KPHX 121120Z 121212 12004KT P6SM SKC FM1800 VRB05KT P6SM SKC TEMPO 2101 29006KT FEW110 FM0100 29005KT P6SM SKC
D-ATIS	PHX ATIS INFO N B8 10006KT 10SM CLR 27/07 A2991 TWO NINER NINER ONE. RWY 8, RWY 7L IN USE. SIMUL APCHS IN USE. EXPECT FWY VIS RWY 7L OR VIS APCH RWY 8. ACFT FROM NORTH EXPECT RWY 8 ACFT FROM SOUTH EXPECT RWY 7R. NOTAMS...RWY 7R CLSD. ...ADVS you have INFO N.. .

TABLE B

KPHX	Latest METAR	TAF Forecast			
WHEN (Z)	13:56	12:00-18:00	18:00-21:00	21:00-01:00	01:00-12:00
WIND	110° at 6 KT	120° at 4 KT	Variable° at 5 KT	Variable° at 5 KT	290° at 5 KT
				TEMPORARY: 290° at 6 KT	
VISIBILITY	10 MILES	6+ MILES	6+ MILES	6+ MILES	6+ MILES
WEATHER	None	None	None	None	None
CLOUDS	SKY CLEAR	SKY CLEAR	SKY CLEAR	SKY CLEAR	SKY CLEAR
				TEMPORARY: FEW at 11,000 FT	
TEMP	27° Celsius				
DEWPOINT	7° Celsius				
ALTIMETER	29.91				

TABLE C

[0050] Table C illustrates a sample of weather and operations data available from KPHX (Phoenix Sky Harbor Airport) using METAR, TAF and D-ATIS data sources. METAR data may be obtained from http://weather.noaa.gov/weather/metar.shml.

[0051] Table D. illustrates a sample of weather data available from KSDL (Scottsdale, Arizona Airport) As illustrated in Table D, only METAR data is available from this airport.

KSDL	Data Messages
METAR	METAR KSDL 121353Z 00000KT 10SM CLR 22/11 A2994 RMK AO2 SLP115 T02170111
TAF	not available
D-ATIS	not available

TABLE D

[0052] Once data has been obtained from one or more of the data sources listed above (or other data sources within the spirit and scope of the present invention) correlation of operational events and operational information take place. Figure 8 illustrates an example where the airport is running standard approaches into Runway 12. The nominal standard approach is shown from the southwest to the airport. Note that most airports have multiple standard approaches and only one is shown for this example.

[0053] Gates are shown to bound nominal flight paths, and the user can select gates which represent a statistical arrival pattern, which in this example may be set at 99.9%, which is roughly equivalent to three times the standard deviation.

[0054] On an automated basis these gates would declare an operational event when an aircraft exceeded this pattern or blundered through the gates. In the example shown below, the aircraft on approach is shown as following the nominal path and then at some point on the approach the aircraft heads northeast, approaches and lands on Runway 17. Since the aircraft exceeded the gate limits, this event would then be logged accordingly.

[0055] In this example, it is assumed that the aircraft in Figure 8 also violated the airport noise abatement procedure, as

approaches to Runway 17 are not permitted between 10 PM and 7 AM. If the airport received noise complaints about this event, the airport may be able to automatically identify the aircraft but could not automatically identify the reason for the last minute runway change. Thus, in the Prior Art, if the airport wanted to follow-up on the reason for the deviation it would have to manually talk with tower personnel and perhaps the aircrew. This would be unreasonable at a busy airport that receives thousands of complaints per year.

[0056] The exceedance described in Figure 8 is a particular example and a list of aircraft approach exceedances can be found in Cassell, R., Smith A., Cohen, B., Yang, E., Sleep, B., A Prototype Aircraft Performance Risk Assessment Model, Final Report, Rannoch Corporation, February 28, 2002 and Cassell, R., Smith A., Cohen, B., Yang, E., Sleep, B., Esche, J., Aircraft Performance Risk Assessment Model (APRAM), Rannoch Corporation, November 30, 2002, both of which are incorporated herein by reference. Other exceedances that may be incorporated into this approach include speed, altitude, lateral (short duration), as well as lateral (long duration) as is illustrated in Figure 8. Any one of these exceedances can be used as a filtering event to correlate aircraft, airport, and environmental data.

[0057] Figure 9 is an example of Logic used to Classify Operational Events. These events may include altitude exceedance 910 which may include instances where an aircraft varies from its assigned altitude by a predetermined parameter. Lateral exceedance (long duration) 920 may include instances where an aircraft varies from its assigned flight path for extended periods of time (as in the Example of Figure 8).

[0058] Lateral exceedance (short duration) 930 may include events where an aircraft exceeds its assigned flight path for short periods of time, but is quickly corrected. Speed/thrust exceedance 940 indicates events where an aircraft exceeded its assigned speed by a particular margin or expected thrust (as determined by acceleration and/or rate of climb) by a predetermined margin.

[0059] Continuing with the example of the long duration lateral deviation of Figure 8, the D-ATIS and other information is collected and analyzed. Thresholds 915, 925, 935, and 945 are preset for different parameters. For example the low ceiling parameter 970 may be given assigned value for the airport as well as "low" visibility. Thus, what constitutes "low ceiling" may vary from airport to airport or may be adjusted.

[0060] Similarly, other parameters such as "low visibility" 950 may be determined by threshold 915. TCAS advisory 960 may be determined by threshold 925. ATC instruction may be determined by threshold 945. When each of these data elements exceeds a threshold parameter or equals a predetermined value, the value may be combined in step 990 to form query results.

[0061] Note that all of the raw data area available for sorting by the airport but the establishment of present thresholds allows the system to automatically give possible classifications of operational situations. Note also that the thresholds, data sources, and parameters illustrated in Figure 9 are by way of example only and are not limiting within the spirit and scope of the present invention.

[0062] In the above example, which shows only a sample of operational parameters, the combinations and automatic classifications illustrated in Figure 7 are possible. Figure 7 is a table illustrating the combinations and automatic classifications possible with the logic of Figure 9.

[0063] As illustrated in Figure 7, the event information may contains occurrences at the airport, such as fuel spills, construction activities, or problems with ATC equipment, such as

Radar. Possible reasons are given based on an auto-sort of information. In some possible combinations the reason seems quite clear, such as the aircraft TCAS received a warning and the pilot took evasive action to maintain aircraft separation.

[0064] If this was prevalent at the airport in certain conditions the airport could analyze the operational procedures in a given set of conditions to determine whether the number of go-arounds or missed approaches could be minimized. Some of the scenarios may need further information such as scenario or combination 2, where the aircraft was instructed to switch runways. This could be provided automatically from the other information from sources such as D-ATIS, for example a fuel spill on the main runway, or another aircraft occupying the main runway.

[0065] The present invention may thus provide an automated correlation of cause and effect for airport noise and other events. As stated previously, due to the high number of operations at airports, any system that correlates the effect (flight track exceedance, noise event, and the like) with the cause (weather, operational procedure, incident, and the like) may need to do so in an automated fashion. This is accomplished in the present invention by applying knowledge-based rules to the

combination of events at the airport. Knowledge-based rules apply the operational experience to the combination of events.

[0066] For example, a TCAS traffic advisory or resolution advisory flowed by the pilot breaking off an approach means that it is highly likely the pilot decided to go around or conduct a different approach after receiving the TCAS warning and being concerned about loss of separation from other aircraft. Like wise, any runway change for landing after a warning is issued for fuel spill, construction, or weather event is likely because the pilot wanted to avoid to potential problems on the main runway. High crosswinds on certain runways would also likely cause changes in landing procedures at the airports.

[0067] More information on the application of knowledge-based rules to exceedance analysis is provided in Cox, E., A., Fuzzy Logic For Business and Industry, Charles River Media, 1995 and Smith, A., Cassell, R., Cohen, B., An approach to Aircraft Performance Risk Assessment Modeling, Final Report, Rannoch Corporation, March 1999, both of which are incorporated herein by reference. Knowledge-based rules may be enhanced as the system learns from various data events. If a previously unknown cause-effect scenario occurs, the cause can be entered into the system,

and subsequent events with similar data features then properly analyzed.

[0068] While the preferred embodiment and various alternative embodiments of the invention have been disclosed and described in detail herein, it may be apparent to those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope thereof.

[0069] For example, while disclosed in the primary embodiment as using multilateration data to determine aircraft flight track, other types of aircraft tracking systems, including air traffic control radar, may be used without departing from the spirit and scope of the present invention.

[0070] Within the spirit and scope of the present invention, different ways may be used to obtain the operational data. Once the system obtains the operational data it may be correlated with flight data in real-time or afterwards (post processing). For example it is possible to get the data directly at the airport off-air using a receiver, or it is possible to get it from other central sources such as FAA networks or third party networks, such as the ARINC SkySource or WebASD network. (www.arinc.com).

[0071] Before the development of the present invention, the industry has only considered a data feed from standalone airport noise weather systems such as the Airport Surface Observation System (ASOS). This was specified as a data feed in some specifications for airports, for example in the Specifications for a Noise and Operations Monitoring System for Louisville International Airport, developed by Noise Consultants HMMH, in mid 2003. (See, e.g., TECHNICAL SPECIFICATIONS for an AIRCRAFT FLIGHT TRACK AND NOISE MANAGEMENT SYSTEM for the REGIONAL AIRPORT AUTHORITY OF LOUISVILLE AND JEFFERSON COUNTY, Harris Miller, Miller & Hanson Inc. 15 New England Executive ParkBurlington, MA 01803 HMMH Report No. 298950, incorporated herein by reference)

[0072] Rannoch Corporation was selected for this contract and started work in September 2003, where they implemented a system using the D-ATIS data. Based on the utility of this approach the HMMH noise consultants then incorporated the requirement for a D-ATIS feed as part of the noise system in their next set of Specifications, for Indianapolis International Airport, which was released in November 2003. (See, e.g., NOISE AND OPERATIONS MONITORING SYSTEM INDIANAPOLIS AIRPORT AUTHORITY INDIANAPOLIS INTERNATIONAL AIRPORT 2500 S. HIGH SCHOOL ROAD, SUITE 100 INDIANAPOLIS, INDIANA 46241 October 2003, incorporated herein by reference). Thus, applicant's invention has demonstrated success

in the commercial marketplace by satisfying a long-felt need in the industry.